WinDS of Change

An NREL computer model shows us how and where to use the wind energy systems of the future, and more.

At NREL, as in other research centers, every scientific discovery starts out as a theory. But before that theory can be tested, one R&D process is necessary to make sure the glimmer in the theorist's eye is even feasible: analysis.

NREL's strategic energy analysis capability is one of the laboratory's core competencies and a must-have element of every technology development process. But because analyses are often only as good as the tools the analysts have to work with, key models need to be designed to produce credible, reliable analyses that support NREL's research.

NREL analysts Walter Short (left) and Nate Blair are the originators of WinDS, a software tool for modeling the deployment of wind power technologies.

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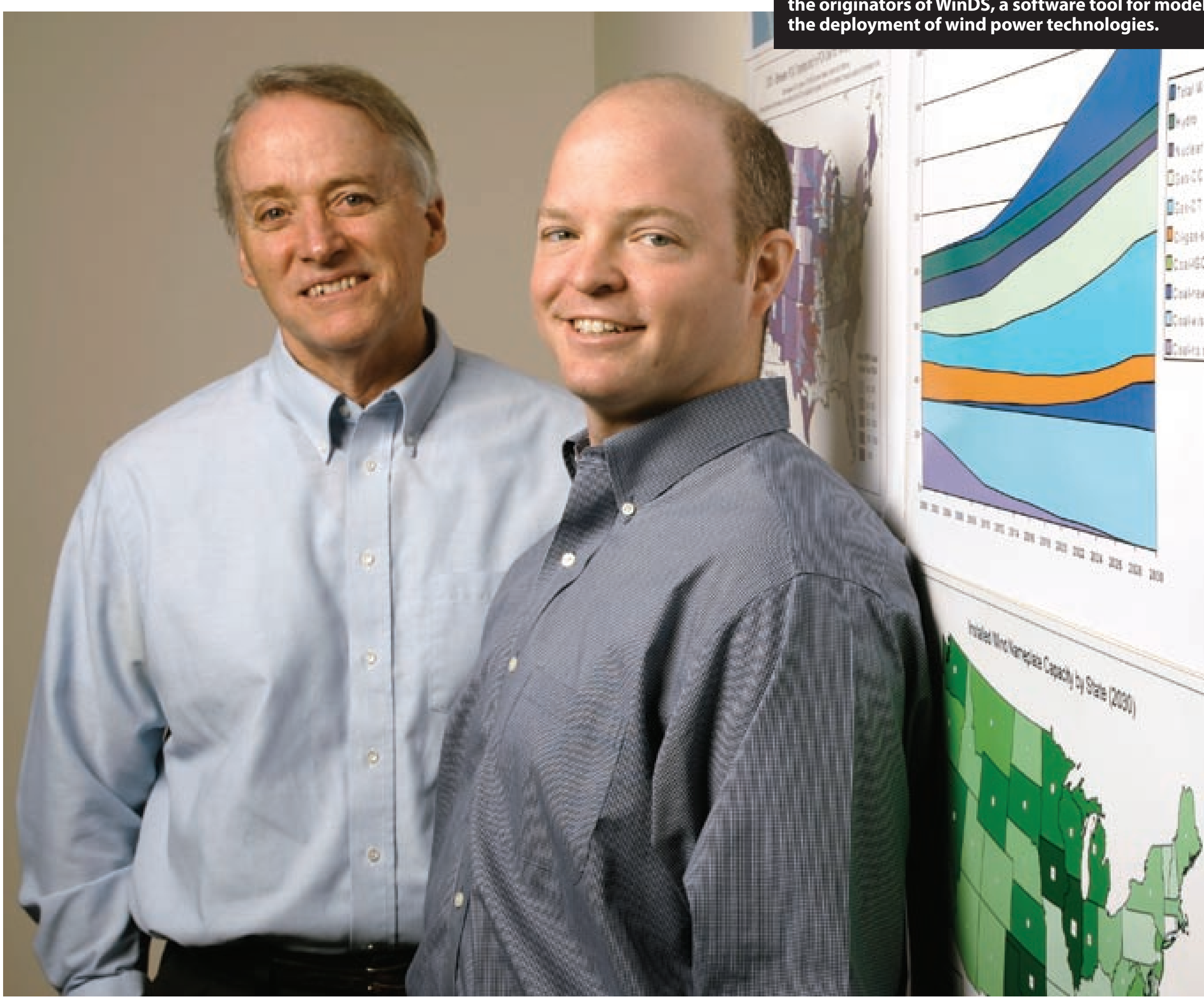


An analysis model starts with a software capability carefully programmed to make use of various inputs to produce a variety of outputs. Although many good energy models exist that different analysts and organizations use throughout the world, customized models are often required to meet individual researchers' needs. NREL discovered such a need while preparing to expand research in wind resources and to examine how to increase the amount of installed wind power capacity in the United States.

Starting with a Spreadsheet

What started out as a spreadsheet on one analyst's laptop has become one of the most credible models for projecting wind power capacities and energy deliveries for the future, and it has a name to match: the Wind Deployment System, or WinDS.

The WinDS concept became reality in 2001 when NREL's Wind Technologies Program requested an analysis of the feasibility of low-speed wind turbines in the United States by evaluating load and transmission requirements. NREL's Walter Short, a group manager in NREL's Strategic Energy Analysis Center, started with a simple spreadsheet model that drew on the geographic information systems expertise of NREL Scientist Donna Heimiller.

Short then took the spreadsheet and spent countless hours, along with an intern from the Colorado School of Mines, to develop the first version of WinDS. The model was able to find the optimal value for wind power capacity based on the wind resource, the available transmission lines, and the electrical load requirements. Short was soon joined in the effort by NREL Analyst Nate Blair, who provided his insights based on other analysis tools, while Heimiller helped to beef up the geographic aspects of the model.

The result was a new model unique in its ability to "regionalize." The model provides a solid, detailed analysis of wind that goes far beyond more simplistic models that consider only a few regions in the United States. The new regionalization capability makes it possible to evaluate numerous site-specific wind resources.

"The modeling capability provided by WinDS is unique in the field," says Bobi Garrett, NREL associate director for Strategic Development and Analysis. "The major national models cannot deal with the wide variation in regional energy resources, demand, policy, or physical infrastructure."

In developing WinDS, NREL sought significant input from a variety of wind industry professionals and other relevant researchers. Short took a direct approach, determining what characteristics would be important to capture—such as transmission access and wind resource variability. Taking all these things into consideration, he applied them to all 358 regions designated in the model.

After further testing and expansion, Short began demonstrating WinDS for other labs. As word got out, nonprofit groups and industry representatives alike became interested in applying the WinDS model to their analysis work.

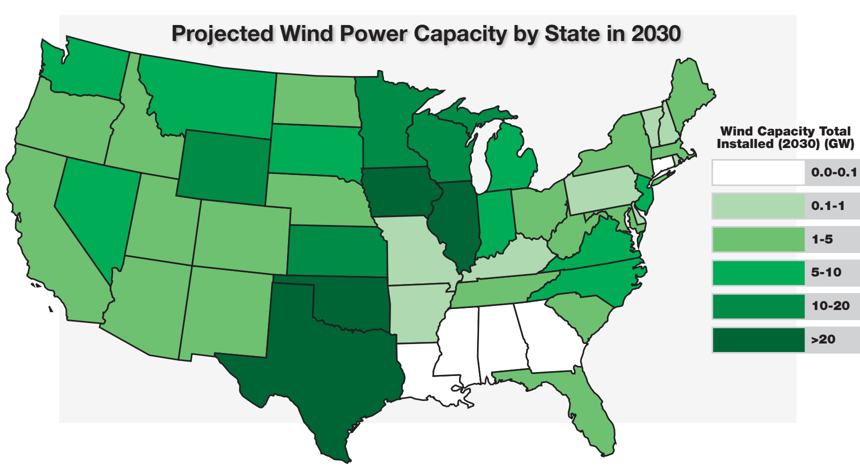
Enabling a National Action Plan

WinDS' regionalization capability is what distinguishes it from other models, such as the National Energy Modeling System. Most capacity expansion models do not have significant geographic capabilities and so cannot track the geographic dispersion of the installed wind energy or estimate transmission costs as penetration levels increase.

WinDS considers key market issues such as transmission system access and cost as well as the reliability of the wind resource. It can determine variability in wind output over time and consider inputs for ancillary service requirements and costs for the 358 individual regions. The model estimates the market potential of wind energy in the United States for the next 20 to 50 years under different technology development and policy scenarios, and it has already yielded important insights.

WinDS' innovative approach to modeling the potential deployment of wind energy addresses many of the shortcomings of large national energy models' representation of the competitive potential of wind energy.

"Many national models rely on assumptions and oversimplify wind energy," says NREL Project Leader Brian Parsons, who works in NREL's Wind Technologies



The WinDS model can examine where wind power will be developed under various scenarios. In this example, which shows one scenario for achieving 20% wind power by 2030, much of the wind power capacity is concentrated in the U.S. heartland.

Program. "This model's attention to detail has ensured accuracy in characterizing technologies and credibility for these numbers."

After President George W. Bush called for producing 20% of the nation's electricity from wind power by 2030, the American Wind Energy Association (AWEA) partnered with DOE and other stakeholders to develop a wind resource action plan. The plan required an analysis of the benefits of, and barriers to, wind production, as well as where transmission would be needed, an analysis that WinDS was able to provide in detail. Using WinDS, the team is analyzing the feasibility and economics of reaching the 20% goal.

"Wind industry and policymakers are very interested in knowing how much U.S. electricity can come from wind, and the WinDS model has proven to be an indispensable tool to evaluate this question," says Rob Gramlich, AWEA policy director. "We have learned a great deal from the model thus far and look forward to sharing these results with policymakers and the energy industry this spring."

NREL has demonstrated WinDS' ability to answer important deployment questions, highlighting transmission possibilities and where resources need to be built. For instance, WinDs uses the 358 regions in its system to show the locations of cumulative wind-power installations needed in 2050 under certain scenarios. As expected, the results show the installations located in areas with excellent wind resources. However, WinDS also shows how it makes sense to locate installations close to major load centers, such as in southern California.

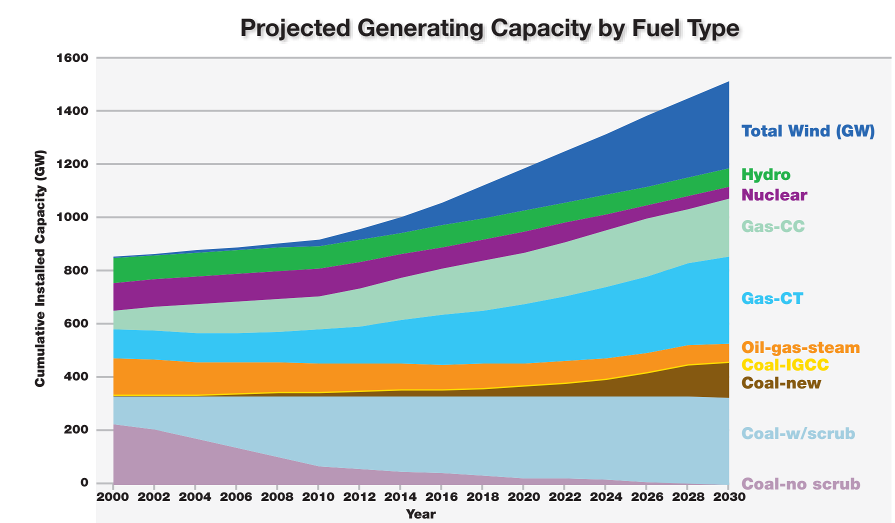
Addressing Specific Markets and Issues

Another practical application of WinDS was an analysis done in 2006 to evaluate the market impacts of specific state-level policies. The analysis looked at national and regional wind energy deployment and generation through 2050 and examined impacts on wind growth associated with state-level renewable portfolio standards (RPS). These standards require utilities to generate a certain percentage of their electricity from renewable energy sources, and wind power is currently the preferred choice. The analysis examined the effects of increased penalties for failing to meet the RPS requirements and also examined other mandates and tax credits.

"The analysis showed that these mandates increase industry size and lower costs, which results in wind capacity increases in states without the rules, and greater market growth even after the policies expire," says Blair. "Although the policies are enacted by individual states, the cumulative effect must be examined at a national level."

Another WinDS analysis examined several potential energy policy cases and how they could affect the U.S. market for wind power, including issues related to the penetration of wind energy technologies into the electricity sector. Principal market issues analyzed included access to and cost of transmission as well as variability. WinDS modeled the impact of various policy initiatives, including a wind production tax credit and an RPS.

The line for WinDS assistance doesn't stop there. The Bureau of Land Management (BLM) also used WinDS outputs within their programmatic environmental impact statement for wind power on the public land that the BLM manages in western states. WinDS was used to forecast the amount of land in the West that could be economically developed. NREL has provided additional results to the National Research Council, General Electric, and other groups interested in the regional-level analysis provided by WinDS.

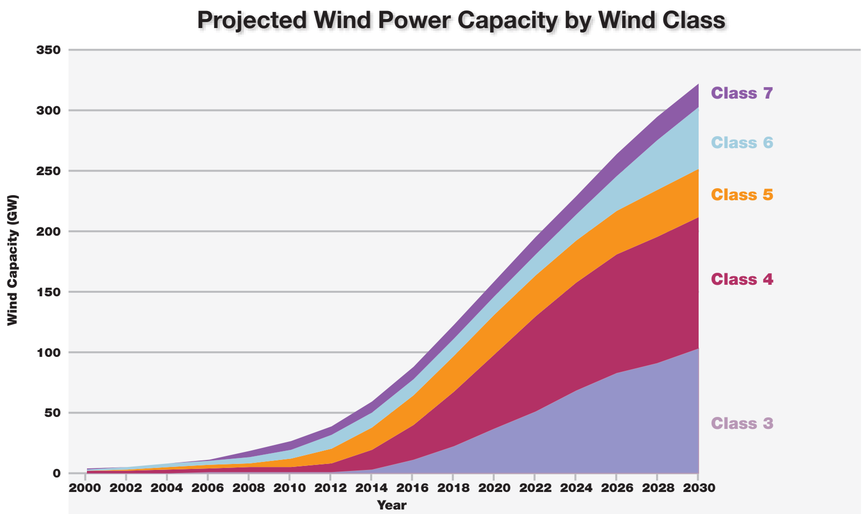


The WinDS model can examine how wind power will compete with other generating technologies under various policy scenarios. This example shows one path toward achieving 20% wind power by 2030, and shows wind competing with a strong growth in natural gas combustion turbine and combined-cycle technologies. The projection shows coal power growing slightly as the industry shifts to cleaner technologies, like integrated gasification and combined-cycle plants, while the generating capacity from oil, nuclear, and hydropower sources declines.

Modeling the Wind, and More

Success increases demand, and many people are hoping that WinDS will be able to do even more modeling in the near future. And NREL analysts have already applied WinDS' unique system to models for other technologies, such as concentrating solar power and hydrogen.

"The capabilities of WinDS have raised



Assuming that the nation will reach 20% wind generation by 2030, this output from the WinDS model shows an increasing need to make use of class 3 and class 4 wind resources—considered "fair" to "good" resources—in the future, following significant near-term exploitation of the "superb" class 7 wind resources.

some awareness within the modeling community of more sophisticated approaches to incorporating wind and other renewable energy technologies into their models," says Sam Baldwin, chief technology officer in DOE's Office of Energy Efficiency and Renewable Energy. "This innovative work also has been extended to hydrogen and solar and is already having a fundamental impact on understanding the potential of renewable energy in the broader market."

For example, the Hydrogen Deployment System, or HyDS, model looks at U.S. market expansion of hydrogen production from wind and other sources over the next 50 years, evaluating future roles and contributions. With the current emphasis on production, it is important to look at the feasibility of producing hydrogen from three competing technologies: wind, steam methane reforming, and distributed electrolysis powered by electricity from the grid. The model has to consider the interconnection between wind and hydrogen as well as hydrogen storage and transportation issues. The resulting data are helping to shape DOE's R&D approach.

WinDS can also measure the interaction between electric and transportation technologies, such as analyzing the benefits of plug-in hybrid-electric vehicles (PHEVs). A PHEV can recharge its batteries with electricity from the electric utility grid. The vehicle can then drive with less gasoline or other alternative liquid fuels such as biofuels or hydrogen. PHEVs have recently emerged as a promising alternative for displacing a significant portion of fleet petroleum consumption.

Using WinDS, NREL analysts carried out a study of PHEVs that can be charged from or discharged to the grid. They found a synergism between PHEVs and wind energy, indicating that the electricity storage capacity of these vehicles can make a difference in the cost-effective wind capacity for the United States.

Finally, the WinDS model is being extended to other renewable electric technologies. The first of these is concentrating solar power, specifically, parabolic trough power plants equipped with six hours of thermal energy storage. Thanks to the lessons learned in constructing the wind features in WinDS, the extension of the model to concentrating solar power was relatively easy, and the new Concentrating Solar Deployment Systems model is already being put to good use.

WinDS of the Future

Although WinDS currently focuses exclusively on the electricity sector, future goals include examining electricity storage options, transmission power flows, carbon sequestration, energy storage, coal plant siting, and a full complement of renewable energy resources, including biomass, geothermal, and ocean energy. With such improvements, WinDS could be used to examine the synergies among renewable energy technologies and analyze such policies as climate change legislation or a national RPS.

One of the items at the top of many modelers' wish lists—especially Short's and Blair's—is for analysts all over the world to put their model's results to work in other analyses. To achieve that goal for WinDS, Short and Blair are currently refining a supply curve that can be used as an input into other models, providing a more sophisticated method of examining the transmission and variability issues associated with wind energy.

NREL is also working with modelers and analysts from a variety of organizations to examine the differences in various energy models. These experts, who have formed the Renewable Energy and Efficiency Modeling and Analysis Partnership, are conducting workshops to look at how outputs differ among the modelers in the group. By looking at these differences, they hope to create common scenarios for all models and improve their ability to evaluate policy decisions. And as these collaborative efforts grow, so does the laboratory's reputation.

"What started out as a single model for a single technology has grown into a suite of leading-edge models," Garrett says. "WinDS has taken NREL from a position of little recognition for its modeling ability to broad acknowledgment for a credible capability." ■